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INTERNATIONAL GEOPHYSICAL COOPERATION PROGRAM -- SOVIET-BLOC ACTIVITIES

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I. GENERAL

Space Research Program of USSR Summarized

The following is a complete translation of a newspaper article which surveys USSR activities in space exploration.

The historic date of 4 October 1957, when the first Soviet artificial satellite was launched, marks the beginning of the era of conquering the cosmos. The weight of the first satellite was 83.6 kilograms.

Within a month after the first, on 3 November 1957, the second Soviet artificial satellite was launched. On board was more complex scientific equipment and an experimental animal, the dog Laika. This satellite weighed 508.3 kilograms.

The third satellite went into orbit on 15 May 1958. It weighed 1,327 kilograms and actually represented a flying scientific laboratory. The next great achievement was made by Soviet scientists, designers, engineers, and workers on 2 January 1959, when the first cosmic rocket was launched. The rocket passed close to the Moon and is forever lost from the Earth, having become a satellite of the Sun, the first artificial planet. These successes stem from the achievements of Soviet rocket engineering.

We shall mention briefly the basic parameters of the satellites. The first satellite lasted for 92 days, the second for 162 days, and the third will last until autumn of 1959. The initial period of rotation of the first satellite around the Earth was 96.2 minutes; of the second, 103.7 minutes; and of the third, 105.95 minutes. The height of the apogee (the point of greatest distance from the Earth) of the first satellite was 950 kilometers; of the second, 1,670 kilometers; and of the third, 1,880 kilometers. The height of the perigee (the point of least distance from the Earth) of the first satellite was 227 kilometers; of the second, 225 kilometers; and of the third, 226 kilometers.

The orbits of all Soviet satellites were inclined at approximately the same angle, 65 degrees, to the plane of the equator. Because of air resistance, the orbits of the satellites gradually changed in both dimensions and shape during their flight. They became less and less elongated and more and more approached the surface of the Earth. Since the length of the major axis of the orbit systematically decreased, the period of rotation the satellites around the Earth constantly shortened in accordance with Kepler's third law. The rate of change in the period of rotation depends on how greatly the satellite is slowed down by the atmosphere. A detailed analysis of the change in the period of rotation of satellites makes it possible to determine certain physical parameters of the atmosphere and their daily and latitudinal variations.

Study of the data from instruments installed on the satellites made it possible to investigate the motion of the satellites around their center of mass. This information is necessary to interpret correctly the results of the measurements.

The multistage rocket launched on 2 January 1959 was the first in history to complete a flight close to the Moon. It passed at a distance of about 5,000 kilometers from the Moon and left the sphere of the Earth's attraction and turned into the first artificial planet of the Solar system. The weight of the scientific equipment and power supplies on the cosmic rocket was 361.3 kilograms. The total weight of the final stage of the cosmic rocket after the fuel had been expended was 1,472 kilograms.

It is interesting to note that it was more difficult to fire a rocket toward the moon in the territory of the Soviet Union than to launch one from lower latitudes. The territory of the USSR cannot intersect the plane of the Moon's orbit which, at present, lies approximately between 18 degrees N and 18 degrees S latitude. This rules out the possibility of using the extremely advantageous trajectories lying in the plane of the Moon's orbit for a flight in the vicinity of the Moon. These trajectories make it possible to fire a cosmic rocket under the most favorable conditions, when the direction of its flight in the launching phase is only slightly inclined to the local horizon. It is of note also that when a rocket travels in the plane of the Moon's orbit, a control system of lower accuracy is necessary for the rocket to pass at a given distance from the Moon.

Not all days of the month are equally favorable for launching a cosmic rocket. The most favorable position of the Moon for launching from the territory of the USSR is when its inclination is a minimum or about 18 degrees S latitude. Any significant deviation from this inclination involves a considerable loss in payload, with a resulting decrease in the amount of scientific equipment, or even makes flight impossible. The day chosen for firing the cosmic rocket was such that the position of the Moon for flight close to the Moon differed but little from the optimum.

The closer the launching point is to the plane of the Moon's orbit, the less is the importance of choosing the optimum date for the flight.

The successes achieved by the Soviet Union in cosmic flights were made possible by the high level of development of our rockets. The latest developments of our science and technology were used in their design and construction. Much scientific research was required to develop the present rocket carriers, and the high level of our industry was relied on. We have created powerful, highly effective rocket engines which use high-calorie fuel. Automatic control systems have been developed for the rocket in flight, which insure stabilization of its position in space and that it exactly follows a a given trajectory in the launching phase. Extremely high accuracy is necessary to put an artificial satellite in an orbit with given parameters or to

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carry out a cosmic flight with a specific purpose. This accuracy must be maintained in the calculated values of the coordinates and the velocity components at the end of the launching phase. The successful solution of this complex problem in the launching of Soviet satellites and the cosmic rocket is the outstanding achievement of modern automation.

The firing of the Soviet artificial Earth satellites and the cosmic rocket yielded results of fundamental scientific importance in the investigation of the upper layers of the atmosphere and cosmic space.

The material below is based on the address of the president of the Academy of Sciences USSR, A. N. Nesmeyanov at the General Assembly of the Academy of Sciences in March 1959. It contains the results of only those experiments on which the development of the scientific data has in large measure been completed.

Investigation of Radiation Close to the Earth and in Cosmic Space

Work on the study of cosmic rays conducted over the past years yielded many interesting results, both toward the solution of the problem of the interaction of elementary particles at high energies and toward the solution of the problem of the origin of cosmic rays. The theory of the origin of cosmic rays in the burst of supernovae link together such phenomena as cosmic radio emission and cosmic rays and offered a new approach to a solution of the problem of the origin of cosmic rays. To verify and further develop the theory of the origin of cosmic rays and to extend our picture of the properties of interstellar and interplanetary space, new and more exact information is required concerning primary cosmic rays and the flow of particles at such distances from the Earth where it is possible to neglect the effect of the Earth's atmosphere and the Earth's magnetic field. It is also necessary to obtain information concerning the change in the intensity of particle flow with time, concerning the "chemical" composition of the particles, and concerning the energy spectrum of the particles.

These were the problems before the cosmic ray physicists in conducting experiments on the first artificial Earth satellite. The result, however, was unexpected: Along with primary cosmic rays at great distances was observed very intense radiation composed of particles of relatively low energy.

An extended investigation of cosmic rays of the Earth's atmosphere was first conducted on the second Soviet artificial Earth satellite. On 7 November 1957, at 4:36 Moscow time, when the satellite passed in the region of the 55 degree geomagnetic latitude, a 50-percent increase in the intensity of radiation was recorded. Earth stations did not record any such increase in intensity at this time. Consequently, this effect was caused by low energy particles which did not reach the Earth's surface.

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A luminescence counter, a considerably more sensitive apparatus, was installed on the third Soviet artificial Earth satellite. By now, a large number of records have been analyzed which were made during the passage of the satellite at various altitudes and over various regions of the globe. It turned out that in all cases, without exception, during the passage of the satellite through the band of geomagnetic latitudes from 55 degrees to 65 degrees, both in the northern and southern hemispheres, a sharp rise in the intensity of X-radiation was observed. Analysis of the data obtained shows that the radiation recorded by the instrument was composed of electrons bombarding the shell of the satellite. The energy of these electrons was of the order of 100 kiloelectron-volts or less. It was observed in these same experiments that the intensity of the radiation increases at greater distances from the Earth. This fact shows that the particles do not arrive directly from cosmic space but undergo oscillations along the force lines of the magnetic field. The Earth's magnetic field constitutes for low energy charged particles a peculiar "trap," in which the particles can move in a practically closed trajectory for the course of a very long time.

It is evident from experimental data that these conditions are not fulfilled at the magnetic force lines intersecting the Earth at geomagnetic latitudes greater than 65 degrees and therefore the regions ajacent to the Poles are free from radiation. The region of space occupied by the radiation mentioned has received the name "outer zone."

More complete data on the outer zone was obtained during the flight of the cosmic rocket of 2 January 1959. Figure 1 [not reproduced] shows the readings of one of the instruments which measured ionization as a function of the distance from the center of the Earth. The distances along the horizontal axis are given in radii of the Earth. Along the vertical axis is indicated the intensity of the radiation in electron-volts per second. As the distance from the Earth increases, the radiation intensity at first increases by a factor of 100, reaching a maximum at a distance of 4 radii from the center of the Earth, and then sharply decreases. A constant level is reached beyond the limits of 10 radii of the Earth. This corresponds to the Cosmic radiation in interplanetary space.

Instruments on the Cosmic rocket made it possible to make a more precise measurement of the extent of the outer zone in space and to obtain new information on the composition of the charged particles in this zone. The effective energy of the electrons in the vicinity of the maximum is about 25 and at the boundary of the zone, about 50 kiloelectronvolts. After the rocket passed from the outer zone, at a distance of about 10 radii of the Earth, the same instruments measured with high accuracy the intensity of the primary cosmic rays and also the hard electromagnetic radiation (X-and gamma-radiation) in interplanetary space. In addition to the outer zone of high radiation intensity described above, there exists a second, an inner zone. Experiments on US satellites detected a high radiation

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intensity in the region of the Equator at an altitude of less than 1,000 kilometers. Extensive data on this phenomenon were obtained with the third Soveit satellite. It turned out that charged particles of the inner zone occupy a region from 35 degrees North geomagnetic latitude to 35 degrees South geomagnetic latitude at an altitude of about 1,000 kilometers. The altitude of the lower boundary of the inner zone was different in the Eastern and Western hemispheres. In the Eastern hemisphere, it was 1,500 kilometers and in the Western hemisphere, 500 kilometers. This is caused by the displacement of the magnetic dipole relative to the center of the Earth. As distinguished from the outer zone, more high-energy particles were observed in the internal zone. Analysis of data obtained on the third Soviet satellite indicated that these particles are protons with energies of the order of 100 million electron-volts.

The hatched section in Figure 2 [not reproduced] shows the outer limits of the outer zone discovered by Soviet physicists. The darker part indicates the high-energy proton zone.

An attempt was also made to record particles with a very small half-life with the third artificial Earth satellite and the cosmic rocket. Intense streams of such particles were observed. These are electrons having an energy of around 10 kiloelectron-volts. They move, as a rule, in the direction approximately perpendicular to the magnetic force lines. The intensity of this radiation evidently increases from the Equator to the Polar regions. It extends to distances equal to several radii of the Earth.

There was discovered a phenomenon which it must be assumed will throw light on a number of phenomena occurring in the upper atmosphere. Up to now, there is no satisfactory explanation of the phenomenon of Polar Auroras. The intense particle streams observed may give a key to an understanding of this phenomenon. Actually, close to the Earth, there is always a considerable energy store in the form of fast-moving electrons. A portion of these electrons may periodically burst into the lower-lying layers, and possibly this causes the Polar auroras.

The fast electrons collide with atoms and molecules of the upper atmosphere and produce X-rays, particularly in the zone of maximum dispersion of the Polar Auroras. The atmosphere of the Earth becomes a source of X-radiation. This radiation, which arises at an altitude of less than 100 kilometers, causes ionization of the more dense layers of the atmosphere.

Another portion of the X-radiation passes into outer space. Thus, the Earth, and possibly other planets, can be a source of X-rays.

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The problem of the nature and origin of particle auroras around the Earth occupies the center of attention of physicists, geophysicists, and astrophysicists. Too little time has passed since the discovery of this new phenomenon. It is, therefore, still impossible to make any choice among the various hypotheses proposed to explain it.

At an assembly of the special committee of the IGY, which was held during the summer of the past year in Moscow, the following hypothesis was advanced. The Earth, as does any other celestial body, becomes a source of neutrons under the action of cosmic rays. These neutrons arise due to the breaking up of atomic nuclei present in the Earth's atmosphere through cosmic rays. Not having an electric charge, the neutrons move away from the Earth unhindered and pass through its magnetic field. Close to the Earth, some of the neutrons decay and produce electrically charged particles, electrons and neutrons. Since they have comparatively low energies, these particles are locked in the magnetic field of the Earth. They can neither enter the Earth's atmosphere nor fly into interplanetary space. They consequently will move about for a very long time in the magnetic field at a distance of the order of thousands and tens of thousands of kilometers from the Earth. The number of atoms which are present at such distances from the Earth is very small; therefore, collisions with atoms are extremely rare and consequently the energy of these particles will decrease very slowly. Over a long interval of time, there will be a great accumulation of these particles and the radiation intensity will be high. At present, it may be considered established that it is this process that causes high energy protons in the outer zone. For a complete explanation of the structure of the inner zone it will be necessary to determine by what process the particles leak from the zone and produce its limit in space. Two hypotheses have been posed in this regard. One of these proposes a sharp increase in the leakage of high energy protons at high altitudes because of the weakening of the magnetic field. The other hypothesis proposes the leakage is due to the fast oscillations of the magnetic field at geomagnetic latitudes greater than 35 degrees.

The more promising hypothesis to explain the origin of the outer zone is the one in which the phenomenon is ascribed to the action of streams of charged particles coming from the Sun. Bunches of charged particles are ejected from the Sun during periods of increased solar activity. Portions of the magnetic field of the Sun are also carried away in these bunches. The magnetic field of these bunches can become traps in which a considerable number of the particles formed on the Sun accumulate. These particles can then be "injected" into the trap formed by the magnetic field of the Earth. As a result, particles carried from the Sun appear close to the Earth.

Finally, it should be mentioned that if products of atomic explosions reach great altitudes, they create there intense streams of charged particles. Since the energy of these particles is small, they are apparently caught in the magnetic trap. Atomic explosions may consequently lead to "contamination" of the regions of the cosmos close to the Earth.

Although no more than half a year has passed since the firing of the first Earth satellite on 4 October 1957, the flights of satellites and cosmic rockets have led to outstanding discoveries. The seemingly empty space around the Earth has now become an arena of phenomena which are extremely important in a practical and scientific sense. A prediction which is of fundamental significance for astrophysics may be made that such an aureole of particles will surround every celestial body which has a magnetic field. The properties of the cosmos change considerably in the vicinity of planets and the extent of this change is much greater than the extent of the atmosphere of these bodies. According to data obtained on the cosmic rocket, cosmic rays in interplanetary space cannot cause any catastrophically harmful effects on the organism of future astronauts. It should be mentioned though, that this conclusion refers only to a relatively quiet state of the cosmos, as was the case during the flight of the cosmic rocket.

In the region of maximum radiation close to the Earth, the intensity is very great. The bombardment of the space ship by fast particles must therefore be taken into account during the passage of a cosmic ship close to the Earth and, possibly, other planets. This can lead to radiation sickness in living beings.

Is protection from this radiation possible? The data obtained indicates that in the external zone protection is possible, although it would require an increase in the weight of the cosmic ship. In the internal zone, particle energy is very high. The construction of an effective shield would require an extremely great increase in weight. The trajectory of rockets on which future astronauts would fly must therefore be chosen in such a manner that the time the ship spends inside the zones, particularly the inner zone, would not be extensive.

An instrument to study the question of whether superheavy nuclei are present in cosmic waves was placed on the third artificial Earth satellite. The Cerenkov detector recorded nuclei with a kinetic energy greater than 300 million electron-volts per nucleon. The instrument was designed to record two groups of nuclei, those with a charge greater than 15 and those with a charge greater than 35. Analysis of the data indicated that only one particle with a charge greater than 15 passed through the instrument per minute. In ten days, there was only one instance of the operation of the channel designed to record the more heavy nuclei. Thus it can be assumed that the flow of heavy nuclei is very small. This fact is of considerable importance for the further development of the theory of the origin of cosmic rays.

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Investigation of the Upper Atmosphere

One of the most important reasons for launching the satellites and rockets was the study of the structure of the upper atmosphere, the region extending approximately from 200 kilometers to the outer limit of the atmosphere. Investigation of the upper atmosphere is concerned with the solution of a number of very difficult problems.

One of these problems is that of the thermal balance in the upper atmosphere. At an altitude of 200 kilometers, the temperature of the surrounding medium is equal to 800-1,000 degrees, and then rises to 2,000-3,000 degrees. The high temperature leads to the comparatively slow drop of the density of the atmosphere with altitude. What are the sources which maintain such a high heat in the upper atmosphere? Some information on this question is offered by the new results obtained with the aid of the satellites and rockets mentioned above.

There is no less difficulty in attempting to explain the ionization data in the upper atmosphere, i.e., the process by which equilibrium is established between the production of free electrons and ions and neutralization. Experimental results differ from the theoretical calculations by thousands or tens of thousands. If we start from the assumption that the neutralization process occurs through the uniting of electrons to positive ions at the expense of the energy of light quanta, it appears that the phenomena which occur here are more complex, involving the participation of other particles, similar to catalyzers, which greatly accelerate the process.

For these particles to control the process of electron neutralization, it is sufficient that they consist of only 1/10,000th or 1/100,000th of the number of neutral particles or the electrons. Positive nitric oxide ions, for example, could serve as such catalysts. These ions were observed at an altitude of more than 200 kilometers by using a mass spectrometer installed on the third Soviet artificial Earth satellite.

All these investigations are of great practical importance. Everyone knows that it is due to the electromagnetic properties of the ionosphere that radio waves propagate over great distances.

One interesting problem can be pointed out in this connection which was known earlier but was clearly verified through observations on the signals of the Soviet satellites. This phenomenon is called the antipode effect and consists of the following: power of a signal received increases at a point situated at the antipode of the transmitting station. From recordings of the radio signals from the first satellite received at Mirniy in the Antarctic it is evident that radio signals from the satellite were received on a frequency of 20 megacycles when the satellite was in the region of the Mirniy Camp and at the antipode. Such cases are of great interest when favorable conditions for the flow of radio waves to a diametrically opposite point of the Earth exist in the ionosphere for an extended period of time.

The negative role of the ionosphere, from a practical point of view, is also well-known. If radio methods are used to control future interplanetary ships, the effect can lead to errors in determining their coordinates, velocity, etc. It is important to know the structure of the ionosphere to avoid these errors. In the light of the above, the value of the results newly obtained by the Soviet scientists will be more understandable.

In the investigations of the upper atmosphere, the determination of its density occupies a leading position. Until the launching of the first Soviet satellite, sufficiently useful data had been obtained for altitudes only up to 150-180 kilometers. Density data obtained for altitudes up to 250 kilometers by various methods were extremely doubtful, and what the density of the atmosphere was above 300-350 kilometers was actually unknown.

Soviet scientists study the density of the atmosphere in various ways. On the basis of the change in the time of the revolution of the satellites around the Earth, a change caused by their slowing down, it was possible to determine with sufficient accuracy at the perigee of the orbit a value which is proportional to the density of the atmosphere.

Manometers of a special type were first installed on the third satellite. These were used to measure density in the altitude range from 225 to 500 kilometers. In addition, the average change in the density of the upper atmosphere at altitudes of from 320 to 1,000 kilometers was calculated on the basis of the electron concentration, which was determined from radio signals of the first and second satellites. Also used was an original method based on observing the dispersion of a cloud of sodium vapor formed at an altitude of 430 kilometers by a high-altitude rocket. The character of the dispersion of this cloud was used to calculate the density at the indicated altitude on the basis of diffusion theory. A similar cloud was later used on the Soviet cosmic rocket to create an artificial comet.

The results of the density determination are given in Figure III. The graph shows, on the basis of the latest data the density calculated in the number of neutral particles per cubic centimeter.

These investigations, which complement one another, made it possible to determine positively for the first time the density of the atmosphere up to altitudes of 600-800 kilometers. They showed the error which existed in a number of representations which had been used to construct

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models of the atmosphere for the launching of the satellites. Regular observations on the slowing down of the satellites made it possible to determine latitudinal and daily changes in the density. Certain data on the temperature of the upper atmosphere was also determined on the basis of the slowing down of the satellite. At altitudes of 228 and 368 kilometers, respectively, the temperature varies within the limits of 800-1,500 degrees.

A mass spectrometer installed on the third satellite was used to obtain a large number of mass spectra of the positive ions which characterize the chemical composition of the ionosphere at altitudes of 226-1,000 kilometers. The measurements were conducted over the interval of mass numbers from 6 to 48 atomic units. It was established from the mass spectrometer measurements that ions with mass number 16 are predominant and, consequently, from an altitude of 226 kilometers to an altitude of at most 800 kilometers, the basic gas opponent to which the ionosphere owes its existence is atomic oxygen.

Ions of atomic nitrogen were recorded in addition to the ions of atomic oxygen. Also observed were heavy particles with a molecular weight of 28 and 30 atomic units. The ions with mass 30 may be identified with ions of nitric oxide, and in the light of what was said above, the observation of these at altitudes up to 350 kilometers is a very interesting occurrence and will be of assistance in further refinement of the data for the solution of the problem of the ionization balance of the upper atmosphere. The relative concentration of atomic/nitrogen with respect to atomic oxygen changes from one to 10 percent, depending on the altitude and geographic latitude and also changes with time. The relative concentration of heavy nitric oxide ions and molecular nitrogen drops sharply with an increase in altitude. The number of nitric oxide ions at an altitude of 230 kilometers is 25-40 percent with respect to atomic oxygen.

The large quantity of the material made it possible to discern a definite relationship between all the observed components of the ionosphere and geographic latitude. In particular, at altitudes of 226 to 260 kilometers, there is observed a sharp increase in the concentrations of ions of atomic nitrogen in the region around 68 degrees N latitude. With the data obtained on the mass spectrometer, it was possible to establish that the satellite, during the daytime, had a negative potential averaging about 5 volts.

Important results were obtained in the determination of the concentration of charged particles. Various radio methods can be used on the Earth to study the distribution of the electron concentration only up to the altitude of the main maximum of the ionosphere, which changes under various conditions within limits of about 300-400 kilometers. The change in the electron concentration above the main maximum remained an open question before the launching of the first satellite, although certain investigators assumed, particularly on the basis of data obtained with US rockets, that the electron concentration quickly falls off above the main maximum.

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This question was investigated in various ways in the Soviet Union. Analysis of the trajectories of the radio signals from the first satellite made it possible to determine, the average change in the electron concentration of the outer ionosphere above the main maximum at altitudes of 320-650 kilometers.

The distribution of the election concentration up to an altitude of 470 kilometers was first directly measured in the vertical firing of a Soviet geophysical rocket on 21 February 1958. Similar data were obtained during 1958 through the firing of other rockets. The first direct measurements of the concentration of positive ions were made on the third satellite along its orbit at altitudes of 900-1,000 kilometers. These measurements were made using so-called ion traps. They made it possible to obtain extensive experimental data. Since the concentration of positive ions in the upper atmosphere is close to the concentration of electrons, these same experiments yield information on the electron concentration. Experiments with the traps made it also possible to measure the negative electric potential of the satellite relative to the surrounding medium. On segments of the orbit illuminated by the Sun, potential was equal to one to 7 volts. The value of the negative potential of the satellite may obviously be interpreted as due to the action of fast electrons, whose energies considerably exceed the average energy of atmospheric particles.

The results of the study of the concentration of charged particles above the main maximum of the ionosphere are given in Figures 4 and 5 [not reproduced]. The drop in the electron concentration above the main maximum occurs more slowly than its growth in the lower part of the ionosphere.

Extrapolation of this data to higher altitudes leads to the assumption that the electron concentration at an altitude of 2,000-3,000 kilometers must reach values which are no less than several hundred electrons per cubic centimeter, i.e., equal to the assumed value of its density in interplanetary gas. The atmosphere of the Earth, evidently, extends to at least 2,000-3,000 kilometers and the previous assumption that its boundary extends to approximately an altitude of 1,000 kilometers must be abandoned.

Investigation of Interplanetary Gas

The first experiment to study directly the gas component of interplanetary matter was/made on the Soviet cosmic rocket. Equipment installed on the cosmic rocket was intended to carry out the first stage of the investigations, namely, an attempt at the direct experimental observation of the ionized interplanetary gas in the region lying between the Earth and the Moon. This equipment had four 3-electrode traps for positively charged particles (protons). The net covering was charged to various potentials with respect to the container shell. These instruments did not make it possible to take into account fully the effect of the electric potential of the container relative to the surrounding medium had on the measurements. Therefore, with these instruments, it was impossible to measure exactly the concentration of charged particles. (Such measurements will be made in the future.) Only a first approximation based on the values of the recorded currents could be obtained. These currents which are caused by positive ions in the circuits of the trap collectors characterize the concentration of particles of ionized gas in the path of the rocket.

The results of the experiment are at present still being analyzed. Nevertheless, we can now give certain data representing considerable interest. On the basis of preliminary data, the concentration of positively charged particles at an altitude of 1,500 kilometers in the unilluminated region of the atmosphere is of the order of 1,000 particles per cubic centimeter. With an increase in altitude to 2,000 kilometers (also in an unilluminated region), the concentration of positive particles drops by a factor of approximately 1.5. At distances of 21,000-22,000 kilometers from the surface of the Earth, the concentration of positive particles is approximately equal to the concentration in a shaded region at an altitude of 2,000 kilometers. At distances of 110,000-150,000 kilometers, the currents recorded in the traps permit the assumption that the concentration of positive particles in this portion of the rocket's path is of the order of 300-400 particles per cubic centimeter.

This was the first experiment to make it possible to estimate the concentration of ionized particles in interplanetary space on the basis of direct measurements and not on the basis of indirect Earth observations, which admit of diverse interpretations.

Geomagnetic Investigations

A knowledge of the Earth's magnetic field at great distances above the Earth's surface is of great importance for a number of problems concerning the Earth's magnetism. A number of conclusions of fundamental geophysical importance can be drawn from an analysis of the magnetograms obtained through the use of a magnetometer installed on the third Soviet satellite. According to the current picture of the character of the daily variations in the Earth's magnetic field, one would expect the effect of magnetic purturbations could best be followed when the satellite passed twice through one and the same part of the globe, once during a quiet state of the field and another time during a perturbed state and, if possible, at various hours of the day. The field values measured under these conditions must differ by a value equal to the effect of the external current system or a part of it. Furthermore, this difference must be of opposite sign for the corresponding segments of the trajectory on the morning and evening sides of the Earth, since the positive and negative peaks in the magnetic perturbations exist simultaneously and the satellite intersects these in the course of 12-15 minutes.

Magnetic investigations on the third Soviet satellite conclusively show the presence of ionic atmospheric sources which cause the variation associated with a perturbation in the magnetic field of the Earth. On analyzing the magnetograms obtained from the satellite, 20 instances were observed of short-term (5-8 second) negative and positive peaks in the magnetic field variation. These may be ascribed to special heterogeneities in the ionosphere current systems of a local character crossed by the satellite.

These results are of great importance in constructing a physical model of the ionosphere in the quantitative theory of magnetic perturbations.

Valuable new data were obtained in the investigation of the constant magnetic field of the Earth. The most interesting data was obtained during the passage of the satellite over the East Siberian world magnetic anomaly, the so-called Asiatic maximum of magnetic field strength. Analysis of the magnetograms and a comparison of these with the change in the land values of the magnetic field strength along the course of the satellite's path indicate a gradual drop in the anomaly. This fact is of great value in the solution of the problem of the depth of the sources of world anomalies and of the nature and structure of the magnetic field of the Earth. It is possible from this to draw some conclusion concerning the deep origin of the sources of the East Siberian magnetic anomaly.

The results obtained in the measurements of the Earth's magnetic field which were made with the cosmic rocket are of exceptionally great value. Discrepancies between the measured values of the field and values computed theoretically become quite noticeable at a distance of approximately 2 radii from the center of the Earth and then increase further. The actual field drops off more quickly at a distance of approximately 20,800 kilometers from the center of the Earth, the field has a minimum equal to approximately 400 gammas i.e., of the order of one hundreth of the field strength at the surface. Then a growth in the field strength is observed up to a maximum value of 800 gammas at a distance of 22,000 kilometers, and then a subsequent decrease. This change in the Earth's magnetic field can be explained only on the assumption that the rocket passed through a current layer at an altitude of 20,000-21,000 kilometers. Thus, the changes in the cosmic rocket indicate the actual existence of an extraionospheric current. This fact is of fundamental importance to the theory of magnetic storms and polar auroras and in particular for the critical evaluation of the explanations of these phenomena which exist at the present time.

Also of significance is the fact that the effect of the current layer was observed on a day which was unpeturbed in the magnetic sense and the closest large magnetic perturbation in time (magnetic storm) had occurred almost a month earlier. The system of extraionospheric currents which arises during a very intense period of magnetic storms can obviously exist for an extended period of time. The experimental material obtained will

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undoubtedly be the object of theoretical investigations, both in geomagnetism and in the related fields of geophysics and plasma physics. It will be of great interest in explaining the connection between the measured maximum in the magnetic field and the aureole of charged particles. Besides measuring the Earth's magnetic fields, the magnetometer installed in the third satellite made it possible to obtain data on the orientation of the satellite in space and to study its motion relative to the center of gravity. This data is necessary in deciphering the results of the majority of the experiments which were conducted simultaneously on the satellite.

Micrometeors

A special apparatus to record meteor particles was installed on the third Soviet Earth satellite. It recorded the number of particle strikes and their energy. The energy was determined on the basis of momentum of the pick-up material which was ejected when a meteor particle struck its surface. Starting from the theoretical relationship between the energy of the meteor particle and the momentum and assuming that the air velocity of the particles is equal to 40 kilometers per second, the particles which were recorded during the operating life of the apparatus had masses of from one light-billionth to two hundred millionths of a gram and energies of the order of from 10,000 to 100,000 ergs.

On 15 May 1958, according to a report delivered at the Fifth Assembly of the IGY, an increase was observed in the number of hits, in comparison with the subsequent days. On this day, from four to 11 hits fell on one square meter in a second. On 16 and 17 May, the number of hits decreased by a factor of 4,000, then by a factor of 50,000 and finally became 1/600,000th of the number on 15 May.

The numerical value of the proportionality coefficient between the momentum recorded by the instrument and the energy of the particle will ultimately be determined experimentally (by modeling). It may be concluded from the experiment on the cosmic rocket that particles with a mass close to one billionth of a gram can strike the surface of the rocket once every several hours. As the measurements on the third Soviet artificial satellite and on the cosmic rocket showed, meteor and micrometeor danger is not great.

Biological Investigations

A new branch of knowledge called cosmic biology has now appeared. One of its important problems is to insure the safety of man's flight through space. Experiments conducted with rockets showed that experimental animals quite satisfactorily withstand the effects of the various flight conditions on an organism. The material now accumulated leads one to conclude that no noticeable disturbances occur in the basic physiological functions of experimental animals under conditions approximating cosmic

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flight. Apparently the most complex problem is to insure the safe return of the animals to Earth. Considerable success has now been achieved in this regard. Experimental animals have safely descended from altitudes of several hundred kilometers. Artificial Earth satellites offer great opportunities since conditions on them, from the biological aspect, are closest to the conditions of cosmic flight.

Further analysis of the scientific information from the second satellite offered much new and interesting data. This is concerned chiefly with the prolonged effect of weightlessness. Of great importance is the fact that under weightlessness, there were not noticed any unfavorable reactions on the part of the autonomic functions of the animal. In addition, the animal did not show any considerable motor disturbance.

Figure 7 [not reproduced] shows the dynamics of the changes in the hear activity of the dog Laika at various times during the flight of the satellite. The graph shows the changes in the frequency of cardiac contractions. It is easy to see that the accelerations, vibrations, and noises involved in placing the satellite in orbit caused a sharp increase in the tachycardia frequency which reached a limiting value. The pulse frequency gradually returned to its initial level under conditions of weightlessness. The character of the electrocardiogram waves, the breathing motion, and the motor activity did not show any considerable deviation from the normal.

The changes in the interval of the electrocardiogram, on the whole, corresponded with the change in the frequency of cardiac contractions. This indicates that the conductivity function of the heart muscle did not suffer. In general, the results obtained clearly show that higher animals quite satisfactorily withstand conditions which are close to those of cosmic flight.

Basic Trends in the Development of Cosmic Flights

An outstanding role in the launching of artificial Earth satellites and the cosmic rocket through which the direct study of cosmic space became a reality was played by Soviet scientists, designers, engineers, workers, and investigators. A large amount of the credit belongs to our mathematicians, mechanics, and physicists of the most diverse specialties. Actually, there was not one region of the exact sciences which did not in some way participate in the solution of the huge problem of investigating cosmic space. This synthesis of science and technology brought notable results, which even now permit one to predict what directions the further development of cosmic flights will take.

The development of cosmic flights in the near future will take a number of directions. Satellite flights close to the Earth is one of these; another is the solution of problems concerning flights to the Moon and landing on the Moon. A third is the investigation of cosmic space, planets of the solar system, and flights to other planets.

Artificial satellites make it possible to solve a wide range of scientific and applied problems. The first Soviet satellites have already made it possible to conduct a large number of investigations and to study a number of phenomena in the upper layers of the Earth's atmosphere and in the adjacent regions of cosmic space.

Further development of the work on satellites will be to expand the range of scientific investigations and to solve purely applied problems with the aid of the satellites.

It will be useful to create satellites which are oriented in a definite manner in space. Orientation is necessary in solving many scientific problems. Thus, for a number of investigations concerning the Sun, it is desirable that the satellite be oriented on the Sun. An obviously more suitable orientation for investigations concerning the Earth and the atmosphere is one in which one of the satellite's axes is directed toward the Earth, and the other coincides with the direction of its motion in orbit. For astrophysical investigations, it would obviously be reasonable to have a satellite which maintained a fixed position relative to the fixed stars.

An important stage is the preparation for flights of a man on the satellites. This requires the solution of a large number of complex problems concerned with ensuring safety and creating the necessary conditions for the man's functioning both during the periods of ascent and descent, when great excess weight is experienced, and during the period of flight in orbit in a state of weightlessness. The experiment with an experimental animal which was carried out on the second Soviet artificial Earth satellite is the first important result in this connection giving scientists material on how conditions of cosmic flight effect a living organism.

The idea has often been advanced on the possibility of using a system of special satellites for the relay of television broadcasts. This would provide long-range transmission on waves in the ultra-short range without requiring radio relay lines and cables.

Satellites can be used to organize a permanent service for observing the corpuscular radiation of the Sun. This will assist in forecasting the important phenomena which occur in the upper layers of the atmosphere.

It is difficult now to predict all the possible uses of satellites for scientific and practical purposes, just as in the dawn of aviation, it was impossible to predict the many regions of application in the diversified progress of aviation at the present time. The number of problems concerned with landing on the Moon represents the second direction in development of cosmic flights. The flight of the Soviet cosmic rocket marks the beginning of the era of flights to the Moon and flights in the space around the Sun.

The flight of man to the Moon, with landing and subsequent return to Earth, may come in the future, though not in the very near future. The problem of landing apparatus on the surface of the Moon is rather complex. Of no less difficulty is the problem of the later take-off from the Moon and the return to the Earth.

In the still more distant future, in the process of studying the Moon, one can visualize the creation of special stations on the Moon which are similar to those scientific stations which are organized in the inaccessible regions of the Earth, for example in the Polar regions. It is necessary here to point out the extreme complexity of such an undertaking. Its accomplishment would be possible only after considerable progress in rocket technology and the solution of a tremendous number of scientific and technical problems. It may be said, however, that plans which seem today completely fantastic and impossible will be carried out with considerable more speed than it might seem at first glance.

The third set of problems which forms an independent direction in the development of cosmic flights is the problem concerning the investigation of the space around the Sun and planets of the solar system. One of the purposes of the flights within the limits of the solar system will be the direct study of interplanetary media. The sounding of interplanetary space with scientific apparatus will make it possible to determine the density of interplanetary gas at various distances from the Sun and to deetermine the chemical composition of the interplanetary gas. It will give new, extremely interesting data on the intensity distribution and the composition of cosmic radiation in various regions of the solar system and will make it possible to investigate the various forms of solar radiation and investigate the magnetic field of the Sun and its effect on phenomena in the interplanetary media.

Of particular interest is the study of planets of the solar system, chiefly Venus and Mars. Analysis shows that a flight to the planets of the solar system would be most expediently carried out during definite time intervals, when the mutual position of the Earth and the planet makes it possible to carry out the flight with a minimum expenditure of energy in firing the rocket. By sending rockets equipped with automatic instruments to the planets it will be possible to investigate their magnetic field and the radiation belt and to obtain a detailed picture of their surface. It will be possible to study the atmosphere of the planet, to determine its density, chemical composition, degree of ionization, and also to investigate the structure of the surface of the planet and its temperature. Finally, the prospect of investigating the forms of life on other planets is alluring. The flight of man to the planets is a thing of the future; the day, however, will undoubtedly come.

The development of cosmic flights will present science and technology with a large number of complex problems both of a scientific-research and engineering-design nature. For determining trajectory parameters, for transmission to Earth of the results of measurements and information, for the operation of the apparatus, and for transmission of commands from Earth, the problem of long range radio communication is important. With the launching of the first Soviet cosmic rocket, for the first time in history, radio communication was established at a distance of around 500,000 kilometers from the Earth. Flights in the limits of the solar system require radio communication and picture transmission at distances of the order of tens and hundreds of millions of kilometers. This gives particular importance to the problem of creating light, miniature, and very economical radio equipment for the rocket and also powerful transmitters and sufficiently sensitive receivers for use on Earth.

All the equipment of the cosmic rocket must be not only of maximum lightness and economy, but also extremely reliable and capable of operating without breakdown for months or even several years. A duration of this order is characteristic for flights within the limits of the solar system, and there is nothing surprising in this if one remembers the duration of the periods of rotation of the planets. The effect of cosmic radiation and the presence of a high vacuum surrounding the cosmic ship create a special situation for the operation of equipment in the cosmos. An important feature is the necessity of maintaining a definite thermal balance necessary for the normal operation of equipment. One of the great problems of cosmic flight is protection from meteorites.

The number of problems concerned with calculating the motion of cosmic ships represents a new direction in celestial mechanics. For the first time in the history of astronomy, the motion of artificial celestial bodies is being calculated, including such extraordinary bodies as can actively influence the character of their own motion. A study of the motion of such artificial bodies will make it possible to obtain new data concerning astronomical constants of the solar system and gravitational fields. We are witnesses to the birth of a new chapter in astronomy which might be called experimental celestial mechanics.

Progress in the development of cosmic flights, that completely new region of human activity, presents very high demands to science and technology: the application of everything which is of the newest and most advanced, and the creation of new scientific and technical directions. There is no doubt that Soviet scientists, designers, engineers, and workers, inspired by the great program for constructing a Communist society in our country, as advanced at the 21st Congress of the Communist Party of the Soviet Union, will creditably handle the solution of this most interesting problem of our day and we will all be witnesses to new shining achievements of the Soviet Union in conquering cosmic space. ("The Universe Discloses its Secrets: Investigation of Cosmic Space With the Aid of Rockets and Satellites," [unsigned article,] Moscow, Izvestiya, 15 Jul 59, pp 3-4) CPYRGHT

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II. ROCKETS AND ARTIFICIAL EARTH SATELLITES

Equations for Motion of Cylindrical Satellite Given

The differential equations of relative translational-rotational motion of a system of two mutually attracting solid bodies are analyzed. The work is a continuation of an earlier paper (Astronomicheskiy Zhurnal, Vol 35, No 2, 1958.) A particular simplified case in which one of the bodies is a homogeneous sphere and the other a homogeneous material segment is analyzed in detail. Particular cases of this problem are studied and the solution given in series for the case when the length of the rod is small in comparison to the distance from its center to the center of the sphere. It is stated that results obtained are applicable in the study of the motion of a cylindrical satellite or a cosmic rocket. ("One Particular Case of the General Problem of the Translational-Rotational Motion of Two Bodies," by G. N. Duboshin, State Astronomical Institute imeni Shternberg; Moscow, Astronomicheskiy Zhurnal, Vol 36, No 1, Jan/Feb 59, pp 153-163).

III. UPPER ATMOSPHERE

Panoramic Ionosphere Station

The automatic panoramic ionosphere station described in the article is the outcome of several years of efforts on the part of the Chair of Antennas and Radiowave Propagation of the Leningrad Electrical Engineering Institute of Communications imeni M. A. Bonch-Burevich.

The performance characteristics of this station satisfy the basic requirements prescribed by the IGY program. The operating characteristics of the station are as follows: the frequency range is 0.5-28 megacycles; power in the pulse is 15 kilowatts; pulse repetition rate is 50 per second; pulse duration is 100 microseconds; sensitivity of the receiver is one to 2 microvolts when the signal-to-noise ratio is not less than 3; linear-scan indicator assures observations at altitude up to 4,000 kilometers; the panoramic indicator permits observation at altitude up to 1,500 kilometers; the scanning time for the whole frequency range (0.5-28 megacycles) is 15 seconds. The automatic device makes it possible to register the altitude-frequency response one, 2, 4 or 12 times every hour.

The station contains the following units: antenna transmission line, transmitter and modulator, A-scope, B-scope, automatic control unit, master oscillator, receiver, receiving antenna transmission line, power supply unit, electric clock and registering device. The altitude-frequency response curve is recorded photographically on a film. A rhombic antenna with an angle of 160 degrees and supported 50 meters above the ground is used with this station.

At present this station is conducting the IGY observations at the Leningrad Branch of the Institute of Terrestial Magnetism and Radiowave Propagation. ("Automatic Panoramic Ionosphere Station," by Ye. V. Ryzhkov, A. Ya. Bukhterin, N. D. Dymovich, N. I Ivanov and Yu. V. Markov, Leningrad Electrical Engineering Institute of Communications, Kiev, Izvestiya Vysshikh Uchebnykh Zavedeniy, Radiotekhnika, No 2, Mar/Apr 59, pp 227-233)

Irregularities in F Layer of Ionosphere

The spatial and time diversity of amplitude and phase of a single magnetically split signal reflected from the ionosphere, are the principal experimental factors confirming the irregularity of ionosphere structure. As a result of the irregular structure of the ionsphere, we observe "flickering" of radio stars, propagation of microwave for very long ranges, and fading of radio signals.

An ionosphere station was used for investigating the angular diversity of reflected waves from an ionosphere layer and the degree of irregularity of such a layer for different hours of the day and various seasons of the year. The transmitter of the ionosphere station had a frequency band of 17 megacycles, the power in the pulse was 30 kilowatts, the pulse duration was 100 microseconds and pulse repetition rate was 50 per second. A 20-meter delta antenna was used for transmission of the signal. Three receiving antennas placed at the corners of a rectangle with an 80-meter base were used. The superheterodyne receiver had an amplification factor of 10^6 and a band-pass of 17 kilocycles. Its amplitude response was linear up to 80 volts at the output. The receiver output was connected to the oscillograph, which displayed the pulse in the form of a horizontal bright line. Measurement of angular scattering of waves reflected from the F layer and the degree of irregularity of such a layer was begun in August 1957 and has been conducted up to the present time. The measurements were conducted for 24 hours at every 2-hour interval, during certain days of the month (8-10), which, as a rule, included the international days of the IGY program. Single reflected waves from the F layer in the range of 3-17 megacycles were investigated. Two hundred and six measurements were obtained which were suitable for detailed statistical processing.

The investigation has shown that reflection from the F layer in 90 percent of the cases during the day and in 50 percent of the cases during the night were of a specular nature.

The author thanks Professor S. Ya. Braude for guiding the major phases of the investigation. ("Investigation of the Effect of Irregularities in F Layer of Ionosphere on Angular Scattering of Reflected Energy," by N. T. Tsymbal, Khar'kov Polytechnic Institute; Kiev, Izvestiya Vysshikh Uchebnykh Zavedeniy, Radiotekhnika, No 2, Mar/Apr 59, pp 221-226)

IV. GRAVIMETRY

Quartz Clock Used for Gravimetric Measurements on "Ob" Described

A portable quartz clock made at the gravimetric laboratory of the Sternberg Astronomical Institute is briefly described. An account is presented of its application during gravimetric measurements on the sea with a pendulum apparatus and also the results of the comparison of this clock with time signals and other clocks by means of a 22-II printing chronograph. The testing of this clock during a prolonged voyage showed that it fully satisfies all the requirements of gravimetric determinations. As a result of the high constancy of its rate, the errors caused by the measurements of time, which limit the precision of gravimetric pendulum determinations at sea, were entirely eliminated. ("Special Quartz Clocks for Gravimetric Measurements, Their Use on the Diesel-Engine Ship "Ob" During the Antarctic Expedition of 1956-1957," by N. P. Grushinskiy and I. A. Yepishin, State Astronomical Institute imeni Shternberg, Moscow, Astronomicheskiy Zhurnal, Vol 36, No 1, Jan/Feb 59, pp 172-178)

V. OCEANOGRAPHY

Vertical Turbulent Exchange in Surface Layer of Sea Measured Directly

A comparison of methods used by Dobroklonskiy (Dokl.AN SSSR, Vol 58, No 7, 1947) and Bowden (Phil. Mag. 1950) showed that for a determination of the dependence of the coefficient of turbulence K on parameters of sea waves, it was possible to get two different answers, both of which satisfy the dimension of K. To ascertain which of these answers is correct, an investigation was made of the vertical turbulent exchange in the surface layer of the sea. Measurements at sea and a subsequent computation of the coefficient of turbulence K were obtained, respectively, by a direct method (re[illegible]ng of microfluctuations of temperature) and by an indirect method (calculation).

In the use of the direct method, no possibility existed of recording the vertical component of velocity fluctuation; thus, the formula for it had to be simplified. It was found that the coefficient p' (in the function $K = p'a^{\alpha} \lambda^{\ell} T$) decreases with increasing agitation of the sea, and that the coefficient p (in the expression $K = p\frac{h^2}{T}$ for the coefficient of turbulence at the surface of the sea; h and T being relative height and period of the waves) was found to be constant within the limits of measurement.

The average value for p, obtained here from calculations based on the measurement data, was $1.5 \cdot 10^{-2}$, which is close to that obtained by Dobroklonskiy ($2.3 \cdot 10^{-2}$) with a purely theoretical method; the latter's theoretical method is thus presumed here to be confirmed by direct measurement. ("Vertical Trubulent Exchange in the Surface Layer of the Sea," by S. G. Boguslavskiy; Moscow Trudy Morskogo Gidrofizicheskogo Instituta, Vol XIII, 1958, pp 14-20)

Depth and Time Variations of Turbulent Heat Conductivity of the Sea

The many methods of determining the coefficient (K) of turbulent thermal conductivity in the active portion of the oceans can be classified into two groups, direct and indirect. Direct methods employ instrument measurements of the changes of temperature and of the vertical component of the velocity of currents. Indirect methods employ either the differential equation itself, which describes the propagation of heat by means of turbulent thermal conductivity, or the solution of this equation.

On the basis that a knowledge of the coefficient of turbulent thermal conductivity and its variation with depth and with time is necessary for the solution of a number of theoretical and practical problems connected with the study of the thermal balance of the sea, this article presents an indirect method of determining the variation of the coefficient K with depth and with time for several southern seas. The good agreement of the computed results with observations suggests that the procedure used here may be used successfully in the computation of the yearly course of temperature in the active layer of the sea. ("The Yearly Course of the Coefficient of Turbulent Thermal Conductivity With Depth in the Sea," by S. G. Boguslavskiy; Moscow, Trudy Morskogo Gidrofizicheskogo Instituta, Vol XIII, 1958, pp 3-13)

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VI. ARCTIC AND ANTARCTIC

Activities at Severnyy Polyus-8 Drift Station

The station Severnyy Polyus-8 is manned mostly by young Komsomols. This is the 3d month of the station's drift in the Arctic Ocean. The scientific settlement was established about 1,000 kilometers northeast of Ostrov Vrangelya among the pack ice.

Several times a day, Leonid Belyakov and Vadim Uglev, hydrologists, measure the ocean depth, which ranges betweer 1,196 and 334 meters. These data will help to obtain more exact information on the continental slope of the Arctic Ocean.

Yevgeniy Podnebesnikov and Gennadiy Artem'yev, meteorologists and actinometrists, conduct round-the-clock observations of the air temperature and pressure, the wind speed and direction, and atmospheric phenomena. Twice a day, radiosondes are launched, carrying instruments up to 36-39 kilometers.

The scope of scientific work is increasing daily. Observation materials are regularly transmitted to the mainland, where they are used in the compilation of ice and weather forecasts.

Nikolay Kotlomanov and Pavel Borovikov, radio operators, maintain constant radio contact with the mainland. They are also enthusiastic short-wave radio fans. Many radio amateurs are familiar with the call letters "Upol-8" of the station Severnyy Polyus-8. The station was happy to make contact with Yakov Baranov, who works at the station Vostok in Antarctica. Despite the great distance, audibility was good.

During a 2-month period, the ice floe has traveled about 500 kilometers. ("Youth at the Pole," Moscow, Sovetskaya Rossiya, 5 Jul 59)

Glaciological Observations in Antarctica (Conclusion)

Ice slopes (skaty) occupy the largest part of the border zone [of Antarctica]. They have a general incline toward the coast, as well as local inclines toward the channels of outlet glaciers. In the case of ice slopes, the ice moves in one solid front, at least in its surface parts, and the speed of ice movement is not as great as in the case of outlet glaciers. Some sections are practically stagnant; for example, near the Bunger and Western "oases" and near the Obruchev and Greerson Hills. Here the edge of the continental shelf has been arrested in its movement by the large rocky elevations of the bedrock which emerges partially to the surface. In these places ablation balances, or sometimes exceeds, the accumulation of ice moving in from central regions. This is proved by the "live" terminal moraines bordering the edge of the continental sheet near Bunger "Oasis" and near the Vestfold and Greerson Hills, and a number of other places.

Ice Domes (kupola)

In a number of places, relatively small, shield-shaped ice elevations rise above the ice shelf. These are the so-called "ice domes, or caps." Some of these ice domes rise above the open sea in the form of islands; for example, Drygalski Island and Penguin Island. Others are connected with the ice shelf only partially, such as Mill Island and Bowman Island. The foot of a number of ice domes, according to seismic soundings, is below sea level. These ice domes rest on shallow, underwater banks, which are apparently of morainic origin. The largest ice dome-islands, such as Mill Island, Bowman Island, and Drygalski Island, rest on a submarine moraine bordering Davis Sea from the north. The ice domes represent a special type of glaciation. Each one of them has an autonomous source of alimentation, derived solely from local precipitation (snowfall, rime, etc.) The ice dome-islands, as most of the other types of glaciers, have vertical ice walls, about 20-40 meters high, descending to the sea. The ice domes situated on the shelf ice have relatively gentle slopes and usually merge with the shelf ice unnoticeably.

Ice dome-islands originate as a result of: (1) settling of part of an ice shelf on the ocean bottom, whereupon this section of the ice shelf, being less mobile, has the tendency to grow upwards; these ice islands may reach considerable heights; for example, Mill Island -- 320 meters, Drygalski Island -- 290 meters, and Bowman Island -- 250 meters; (2) settling of a large iceberg on a bank, after which the iceberg becomes the core of a growing ice dome; for example, such is the origin of Penguin Island near the northwest end of the West Ice Shelf.

Ice Shelf

Glaciers of this type are located within the boundaries of the continental shelf, or continental platform. They differ from all other types of glaciers, representing huge, flat areas of ice, which is not very thick (200-300 meters). The greater part of the ice shelf is afloat, but it definitely rests on a number of stationary points, either shallow banks or ice domes resting on banks, subglacial rocks or islands.

The ice shelf has a very complicated formation. It is nourished by local atmospheric precipitation, by fast ice and icebergs locked into it, and by drift snow blowing off the continent. The snow accumulates on

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the leeward side of the icebergs, near the foot of the continental ice slope, and in other unc en places. There are two ice shelves in the area explored by the Soviet Antarctic Expedition, the Shackleton Ice Shelf and the West Ice Shelf.

The question of the movement of an ice shelf has not yet been sufficiently clarified. Some explorers, such as A. P. Kapitsa, believe that they move only passively. Others are of the opinion that it is impossible to explain the almost unchanging height of an ice shelf above sea level, considering the large amount of precipitation, unless one admits that the ice shelf spreads out to the sides, in proportion to the accumulation of precipitation on its surface.

It is most likely that the movement of an ice shelf is caused mainly by the influence of the continental ice, especially outlet glaciers; however, it is not impossible that they move independently by spreading out sideways after they reach the critical limit of thickness. Interesting material on the dynamics of the ice shelves was obtained by comparing their outlines according to aerial photographs made in 1956-1957 by the Soviet Antarctic Expedition, in 1937 by the Norwegian Expedition, and in 1947 by the US Expedition. In superimposing these outlines, it appeared that the general areas of Shackleton Ice Shelf and West Ice Shelf had not changed substantially during the past 10-20 years, but that the contours had changed radically in a number of places. For example, the huge wedge-shaped tongue in the northwest part of West Ice Shelf, the peak of which rests on Penguin Island, as photographed in 1957, did not exist 20 years ago. A vessel of the 1937 Norwegian Expedition passed through the area where the shelf now exists. Therefore, this tongue is a new formation.

At the same time, the West Ice Shelf has retreated somewhat from north to south. In the area of Gaussberg, the shelf has grown with the help of icebergs brought here by the current. However, the shelf is being rapidly pushed to the north and there is no expansion in the eastward direction.

The same picture can be found on the Shackleton Ice Shelf. Its western shore has remained without substantial changes, but the huge floating ice tongue of the Denman and Scott glaciers, extending over 50 kilometers into the sea, as shown on all maps based on US aerial photographs of 1957, no longer exists. On the other hand, the northern edge of the shelf, opposite the delta of the Denman and Scott glaciers, is chipped off. It is possible that the huge iceberg, noted by the Soviet expedition in the Davis Sea, actually represents the ice tongue which seperated from the Denman and Scott glaciers.

In the eastern part of the Shackleton Ice Shelf, the area of the shelf has increased considerably. Whereas in 1947, a wide, open lead (Edisto lead) existed between Mill Island and Bowman Island, there is now a wide belt of young shelf ice in this place. It appears, therefore, that shelf ice formations are very flexible.

Drift Glaciers

These are small, but very numerous glacier formations, appearing everywhere on the leeward side of nunataks, steep cliffs, and other irregularities in the surface.

The largest drift glaciers were found near the eastern edge of the Vestfold Hills and Bunger Hills, in the lee of Gaussberg, Mount Brown, and Mount Strathcona. Such glaciers are found in large numbers in the area of Greersen Hills, near Mirnyy, and in other places. They are of minor importance in the total balance of glaciers. ("Glaciological Observations in Antarctica," by L. D. Dolgushin, Moscow, Izvestiya Akademii Nauk SSSR, Seriya Geograficheskaya, No 6, Nov-Dec 1958, pp 19-21)

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